bargaining with boundaries:
the social construction of the emergent spaces of antichaos

by Fiona Coyle

deconstruction and reconstruction

spacethefinalfrontierthesearethevoyagesofthestarshipsciencetoexplorestrange newworldsandseekoutnewlifeformstoboldlygowherenoonehasgonebefore

The seemingly amorphous form above represents a shapeless geography of letters to someone unfamiliar with the grammatical nuances of the English language. Nevertheless, almost unconsciously, in our search for patterns (of meaningful letters, phrases and familiar symbolism) we organize this jumble, 'pun-chew-ating' it into a more digestible form. In other words, a recognizable order emerges from what appears to be disorder. Chaos is rendered intelligible as it is transformed into antichaos.[1] Hence, the insertion of empty spaces and small black markings conjures up the following prologue to *Star Trek:*

Space, the final frontier. These are the voyages of the starship [science]. To explore strange new worlds and seek out new lifeforms. To boldly go where no one has gone before.

In this paper, I seek to explore the social construction of the process outlined above, popularly known as self-organization, a branch of the science of complexity theory. It is a mindset which "complexifies, diversifies, pluralizes and temporalizes the old views of what we call 'reality'" (Best 1991: 201).

Complexity theory opposes static, clear-cut Cartesian boundaries, for its metaphors tend to emphasise mobility as we move from "root" to "route" descriptions of the world, which can challenge the notion of fixed identities (Pile and Thrift 1995: 10). Firstly, continuous, fluid shifts from chaos to order and back again indicate that boundaries are dynamic, as they continuously dissolve and reform. Secondly, when researchers in artificial life (colloquially known as Alife or A.L.) argue their computer-based simulations to be representative of the "real" world, the imposed boundary between the artificial and natural is challenged.

Katherine Hayles (1996) contends that the attempt to shake the long-standing boundary between the natural and artificial has been undertaken through story-telling; narratives of Alife are employed in an attempt to redefine life, nature and what it means to be human. In order to naturalise these narratives, scientists have intruded into inherently geographical territory, with the appropriation of words such as "space" and "landscape" into their vocabulary. Although these words are ambivalent in meaning (Duncan 1995; Simonsen 1996), within popular understanding they have relatively natural connotations, providing Alife researchers with a vocabulary to "ground" their theories.

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In order to explore these claims, I shall firstly offer a brief explanation of the underpinnings of complexity theory and the medium through which it is currently being explored. In doing so, attention will be drawn to the dynamic boundaries implied by these worldviews. Secondly, after a brief overview of the theoretical basis for the social construction of scientific knowledge (S.S.K.), there will be a discussion of the construction of complexity theory, primarily through the work of Alife researcher Stuart Kauffman. This discussion applies the framework of Katherine Hayles (1996), in an exploration of the use of Alife narratives to em-body computer codes into conceivable life-forms. As a cultural geographer, my particular focus will be upon the appropriation of the geographical terms space and landscape to ground these theories. Finally, I wish to ask, what impact do these alternative life-forms have on the tentative boundary between the natural and artificial? And what feedback effects have the "artificialization" of the *naturalized,* and the scientific appropriation of space and landscape had on geographical discourse?

identity as a process of self-organization

In the scientific community, there has been much debate over the space encompassed by the term complexity theory (Horgan 1995), for like its predecessor – chaos theory – different schools of thought, the overlap with popular culture and the metaphorical nature of language have resulted in the pluralization of its meaning (Goldstein 1995). Nevertheless, one widely held definition of complexity theory is "the study of the behaviour of macroscopic collections of simple units (e.g. atoms, molecules, bits, neurons) that are endowed with the potential to evolve in time" (Coveney and Highfield 1995: 425).

Consider the image of a flock of birds in flight, and hold it in your mind for a moment. In this aggregate, there exists a non-hierarchical organization, for the birds do not cluster around an individual leader. They gather in a ragged oval, which maintains its form, in continuous motion, like a living organism. This flock is more than just a "big bird", for the behaviour of its constituent individuals is noticeably different from the behaviour of the collective body (Resnick 1994). Or, translated into technical rhetoric, this image portrays "the spontaneous emergence of non-equilibrium structural organization on a macroscopic level due to collective interactions between a large number of simple, usually microscopic, objects" (Coveney and Highfield 1995: 432). Self-organization.

Computers have taken centre "screen" in the field of complexity, with their performance of computational ecologies. As well as the evolution of patterns through the interactions between machines (Lewin 1993), the interactions of cells within a matrix displayed on a computer screen can also give rise to unpredictable patterns from simple rules. Thus, we have the emergence of artificial life; it was from explorations within this realm that the flock of birds metaphor described above emerged.

Exploration takes place in the artificial space of cellular automata (C.A.), a virtual world composed of grid cells. In a C.A. simple transition rules determine how the cells change over generations, based on the states of their neighbours. In more general terms, cellular automata are "a grid of switches that can be set to a number of different positions... a kind of general-purpose programmable factory, that, when provided with a blueprint, can build anything" (Cohen and Stewart 1994: 212; 214). Various types of cellular automata exist (Wolfram 1986), although those deemed class IV exhibit the most complex behaviour. Appropriately, one particular form of class IV C.A. has been named the Game of Life.

Figure 1. Example of a Two-dimensional Boolean Lattice, where each Binary Variable is Coupled to its Four Neighbours. Source: S. Kauffman (1995) At Home in the Universe (1995: 89).

A closely related approach makes use of Boolean N-K networks, consisting of "N elements linked by K inputs per element" (Kauffman 1991a: 80). They are a high dimensional network of binary digits, which can be turned on or off (active or inactive), and have been utilized by Stuart Kauffman as a basis for the (re)creation and evolution of space. One possible configuration is depicted in figure 1.

Although more aesthetic forms of C.A. exist, this two-dimensional array of binary digits is visibly different from the world in which we live. Nevertheless, researchers invite the awaiting audience into the space of possibilities: a voyage into the imagination. In the next section I will investigate the narrative techniques Stuart Kauffman and his associates use to close the gap between the realm of mathematics and the experiential world. Before doing so, I will provide a brief theoretical background on the social construction of scientific knowledge.

myth-making (which is to explain the (re)creation of space)

Since verbal representations of scientific theories are said to be contextually "routed" in the space of social, political and economic concerns (Clocksin 1993), supporters of S.S.K. ask what actually comes to count as scientific knowledge and by what processes does this come to count? According to David Demeritt, empirical studies on the leading scientific representations of the world offer insight into the mediated and embodied knowledge within the research community. Scientific knowledge is dependent upon local conditions and practices, which cannot be translated into general laws and theories. It is acts of use which create and determine meanings, and self-referentially explanatory metaphors construct the nature of the world (Demeritt 1996: 491).

Narratives about the world are discussed and transformed into facts through the local dialect of the laboratory community. As argued by Bruno Latour and Steve Woolgar (1979), when enough supporting statements from a variety of narratives are gathered together, the relationship between representation and reality can be inverted: a statement about the world can be transformed into a fact. Correspondingly, there is a focus on the interactive and interpretive work within the scientific community which leads to this transformation. For Karin Knorr-Cetina (1983), the social construction of nature rather ironically occurs in a highly preconstrucuted *artificial* reality. It is this environment upon which I will now concentrate.

land/slide

for my father, who saw me across this border
before crossing another

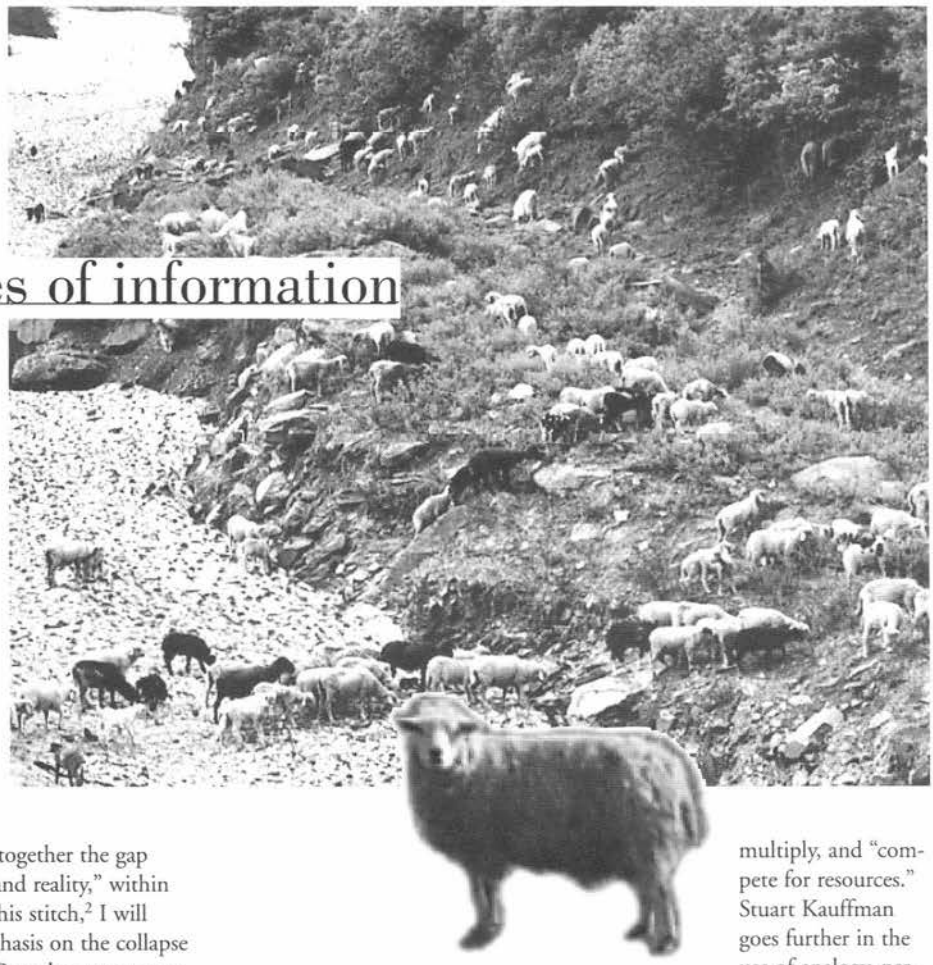
headin' down
head first
over heels
shedding
laddered stockings
(rungs long
out of reach)

tanned legs
don't run
but
slipping south
slither
through
green
brush
riding
the
asphalt
snake

Sheila Hassell Hughes
1992

emphasize mobility as we move from "root" to "route" descriptions of the world...

The arena of Alife is one example of a prefabricated space. Suffering from what Jack Cowan calls the "reminiscence syndrome", researchers exclaim "'look, isn't this reminiscent of a biological or physical phenomena!' They jump in right away as if it's a decent model for the phenomenon, and usually of course it's just got some accidental features that make it look like something" (cited in Horgan 1995: 104). Whether correspondences ring true or not, scientists are confronted with a more pragmatic political



bodies of information

dilemma. Faced with an audience who proclaim, "what good is it?" and see Alife as "a solution in search of a problem," practitioners have little choice but to persuade a skeptical public that their research is more than a mere simulation (Hayles 1996: 156). Thus, their cutting-edge explorations of Alife not only have to be translated into comprehensible terminology, but also have practical, economic applications in a capitalist society. Rather than any results being simply an artifice of the modelling process, they must *become* the underlying properties of natural systems. Thus, by drawing on the similarities to real-world processes and embedding them into explanatory narratives of complexity theory, researchers have conjured up a defense against their critics.

But is this process of naturalization merely stitching together the gap between what Horgan (1995) describes as "rhetoric and reality," within the science of complexity? In an attempt to unpick this stitch,[2] I will draw upon the work of Katherine Hayles. With emphasis on the collapse of the artificial and natural via the work of Thomas Ray, she attempts to "demonstrate how the narrative field in which [Alife projects] position themselves is constructed and how it works to encode premises, authenticate inquiry, and interpolate scientific research programmes with larger cultural narratives" (Hayles 1996: 162).

Traditionally, within scientific discourse the pre-requisite for life has been the presence of organic matter, yet it seems that even before protein began to replicate, there existed a primitive form of life within silicon crystals, which also possessed this capacity for reproduction (Hayles 1996: 157). Coupled with this is a desire to animate the silicon world,[3] for in the opinion of Thomas Ray, the objective of Alife is the introduction of "the natural form and process of life into an artificial medium" (cited in Hayles 1996: 146). Thus, we have the contrived dissolution of the division between the natural and the artificial.

Chris Langton takes this case further and suggests that a complex information dynamics is embedded in living systems, and accordingly, the primary indicator of life should be a behaviour based upon this phenomenon (Langton 1991: 42). Thus, he re-defines "aliveness" as a system capable of spontaneously organising into entities that have the ability to eat, reproduce and evolve (Horgan 1995: 107). For Langton, silicon life should be taken as silicon life and he makes no attempt to extend his narratives into the human world.

multiply, and "compete for resources." Stuart Kauffman goes further in the use of analogy, personifying his narrative with terms like "hill-climbing on rugged fitness landscapes" to describe evolutionary processes.

According to Hayles, these analogies are not contingencies or mere afterthoughts, but an integral part of the artifactual design of the programme. More than merely contriving parallels between the carbon and the silicon, the narratives expose scientific intentions to create a suitable (and natural) environment for the emergence of evolutionary processes. Another example is the transformation of C.A. cells into turtles, which then take on multiple identities, according to the space they inhabit (Resnick 1994). For instance, these turtles can mutate into frogs, artificial ants, slime mould cells or cars. Their reconstructed identities are bolstered by "fairy stories," such as the "storm on a lily pond" narrative employed to set the scene for the reorganization of a community of turtles and frogs.

In all narratives, the concept of a story is implicated, or rather a tale of "epic" proportions, for life is portrayed on a genealogical scale through multiple cycles of birth and death. We have the inscription of centuries of battles, struggles for survival, extinctions, reproduction and adaptation (Hayles 1996: 149). Notably, Stuart Kauffman seizes upon the most revered of all epics: Darwinian evolution. Kauffman's underlying purpose is to challenge and reconstruct the narratives of classical Darwinian evolution. Natural selection was said to act upon what were thought to be ran-

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Nevertheless, Hayles notes that even though self-organization permits Alife forms to replicate within the virtual environment, there still seems to be an irreconcilable discrepancy between these entities and living organisms. Consequently, she asks, how have scientists attempted to counter this problem? The gap is closed somewhat through evolutionary narratives; programmes are mapped into "evolutionary scenarios traditionally associated with the behaviour of living creatures" (Hayles 1996: 148). Within the landscape, "populations" of organisms interact and

dom variations, reducing history to a hasty work of bricolage. Did it stumble forward against all odds to create order, or as Kauffman contemplates, was that order already at hand, ready for selection, as a result of "a spontaneous self-organized property of complex, genetic systems?" (Kauffman 1991b: 76). Based upon Alife research, Kauffman' s answer rules out natural selection as the only, or indeed, most important source of order in the world. His theory is necessarily geographical and pivots around the "edge of chaos."

Consider the edge of chaos to be a very weak form of chaos (another name might be fractal), in comparison to the strong chaos of stochastic, indeterminate systems. It signifies a type of space where "the components of the system never quite lock into place, yet never dissolve into turbulence, either" (Waldrop 1992: 293). These systems are said to self-tune into the edge of chaos, sensing and reading the pre-installed rules, before decoding them into an unpredictable life-form: creating a space where they have the highest potential for productive change.

As aforementioned, the Boolean lattice on which this takes place is strikingly different from the experiential world in which we live, yet Kauffman invites us to follow his imagination, as a fellow explorer of a polar landscape. Thus, furthering the transformation of analogy into fact is the power of the image, whether visual or a textual representation. Kauffman utilizes a partially inverted theory of island biogeography, in combination with a glacial metaphor,[4] making reference to "frozen components," "isolated islands," "percolating walls of constancy" and a "liquid transition phase" to describe the landscape of interacting numbers. Rather than a screen of binary digits, we have a vivid image of the Arctic/Antarctic, allowing us to literally *see* Kauffman's argument.

Following from this, Kauffman asserts that evolution does not act alone and attempts to place this glacial transparency over a mountainous terrain, injecting a flat image with dimensionality. Thus, systems co-evolve,[5] on what he terms, "deforming rubbery fitness landscapes," a dynamic, hybrid form of the artificial and natural. These fitness landscapes may be "smooth and single-peaked, with the peak corresponding to the desired minimum target [of optimum performance] or may be very rugged and multipeaked" (Kauffman 1990: 136).

Although Kauffman's landscapes are fairly modest and are reliant on the imagination, they still fall under the criticism focused upon the visibly "pastoral" landscape of Thomas Ray's "Tierra" program. Basically, Hayles attempts to undermine the reality of representation, for the creatures inhabiting the imagined space represented on the computer screen are at best, only metaphors, their bodies being "bodies of information." In this world, there is no distinction between a genetic code and its corporeal form; the organisms *are* their codes and the codes are the organisms. As Hayles puts it, "the seamless transition between the [computer's interior architecture and the lifeworld of the creatures] elides the difference between the material space inside the computer and the imagined space that, in actuality, consists of computer addresses and electrical polarities on the computer disk" (Hayles 1996: 150-51).

Once grounded, this technological model can become the means to comprehend the inherently human. We can understand the evolution of the carbon through the evolution of the silicon... or so it is implied. Thus, Stuart Kauffman directs his commentary at the evolution of social systems, focusing on political regimes: the frozen order of the "Stalinist regime," the chaotic instability of the "Leftist Italian limit." Finally, he suggests that the edge of chaos is achieved in a democratic system, governed by the "rule of the majority" (Kauffman 1995: 270). Accordingly, if democracy exists upon the edge of chaos, and the edge of chaos is accepted as being a natural condition for evolving organisms, then Kauffman's argument *naturalizes* American democracy at the expense of all other political outlooks. Although Kauffman and some of his peers tread carefully by informing their readers that Alife analogies are extremely loose, widespread societal acceptance of these explanations of reality is ultimately dependent on a correspondence to, or redefinition of what reality is. And as I have suggested, this alternative delineation has shaken a number of boundaries.

bargaining with boundaries: the great, non-linear map in the sky

It seems that in combination with spatio-ecological narratives of Alife, a redefinition of life has resulted in the intersection of the natural and artificial. If life is characterized by form and the ability to (re)form, then silicon-based (artificial) creatures are encapsulated into the description, hence animated. By denying the traditional importance of matter (notably carbon-based) as a pre-requisite for life, the social construction of aliveness is revealed. Thus, it would appear that in the attempt to validate complexity theory, various boundaries have been transgressed: statement-fact, representation-reality, nature-society, natural-artificial and also the boundary defining the spatial territory of geographers.

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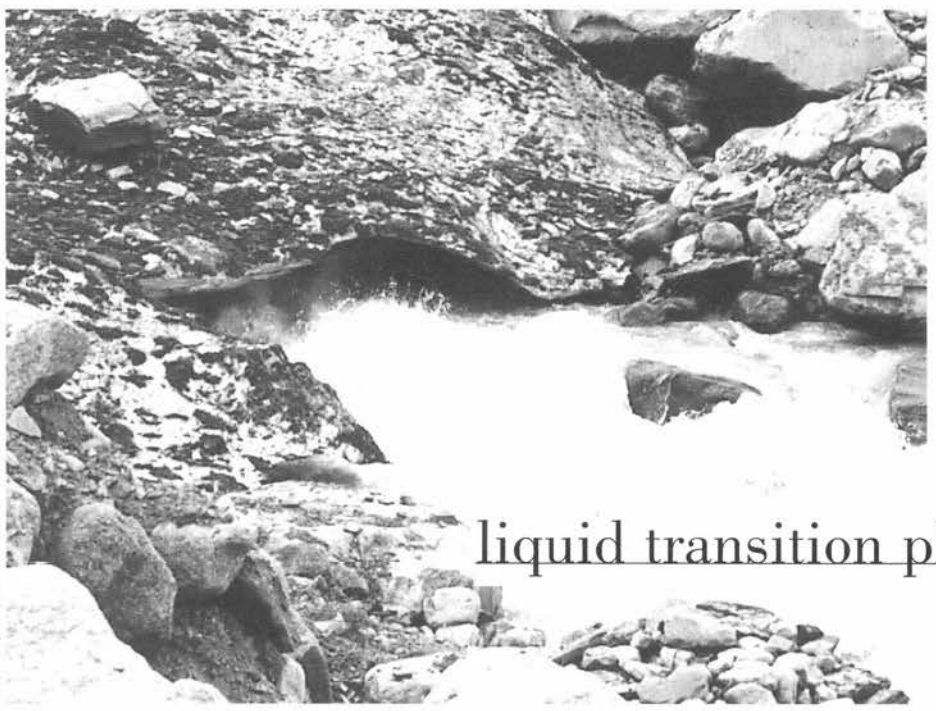
Consequently, I wish to focus upon the feedback effects which the "artificialization" of the *naturalized* and the scientific appropriation of space and landscape have had on geographical discourse.

Complexity theorists have invaded social and geographical space in an attempt to ground and consequently naturalize their concepts. By first appropriating geographical vocabulary to inscribe Alife with meaning and subsequently using Alife models to describe the natural world, the metaphor, "mathematical algorithms as landscape," becomes "landscape as algorithm," when the analogy is *justifiably* reversed. By referring to life as the transfer of information, this not only permits the validation of Alife, but the very concept of living systems is widened to incorporate



Photos by David Pauls, Scott MacPhail

liquid transition phase

societies and cultures which are endowed with characteristics such as the ability to grow, evolve and learn (Plant 1996: 210). The apparently mystical concept of James Lovelock's superorganism, Gaia, is revitalized when it is perceived as a complex system existing on the edge of chaos (Lewin 1996). Furthermore, a "vocabulary traditionally applicable to living systems, such as adaptation, freedom, interconnectedness, spontaneous growth and self-determination" is also expanded to the examination of society (McKie and Bennett 1995: 790).

Additionally, the arguments of scientists become stabilized; by naturalising processes within society, the social construction of knowledge is subsequently naturalized. Complexity theory *becomes* nature as we enter a self-referential loop of "truth by correspondence." Mathematics can now be said to underly the formation of space and landscape, as statement evolves into fact. Alife is grounded, but its existence as an imaginary space (Shurmer-Smith and Hannam 1994: 61) somewhat undermines the materiality of space itself and contributes to the movement away from the conception of space as a material entity (Simonsen 1996).

Photo by David Pauls

Naturally, this has potential consequences for geographical discourse. A naturalized, geographical territory has been colonized by artificial "space invaders." As Alife is granted the power to colonise space, it is injected with dynamism through the use of concepts such as the "space of *possibilities*" and "rubbery, *deforming* fitness landscapes." Consequently, geographical space has become "abstractified" and "artificialized," yet by taking on the attributes of complexity theory, has also been reconceptualized as a dynamic entity with shifting boundaries. "Say a prayer 'to the great nonlinear map in the sky'," reads the ending to Stuart Kauffman's text *At Home in the Universe* (Kauffman 1995: 304). Complexity theory has been mapped, and in doing so, the world is (re)mapped in its image. "The hills are alive" (Resnick 1994) replaces the conception of the landscape as a static theatre stage, awaiting players to bring it to life.

Thus, a questioning of oppositional dualities has led to the construction of "decentred, partial and fractured identities," rendered dynamic through the emergence and dissolution of differences (Simonsen 1996: 502). We are left with an opening for the dissolution of artificial and natural space into a post-colonial hybrid space[6] where the seeming paradox of artificial life can co-evolve with organic lifeforms. Perhaps it is fitting to leave you with the words of the character, Tork, from the novel *Miss Smilla's Feeling for Snow,* who discovered an ancient meteorite preserved under a glacier. A through-flow of energy endowed it with the *appearance* of being alive.

> The true reality of things is not important. What's important is what people believe. They will believe in this stone. Have you heard of Ilya Prigogine? A Belgian chemist who won the Nobel Prize in '77 for his description of dissipative structures. He and his students have been working nonstop on the idea that life originated from inorganic substances through which energy was flowing. These ideas have paved the way. People are waiting for this stone. Their belief and anticipation will make it real. They will make it alive regardless of the true nature of the stone (Hoeg 1995: 403-404).

acknowledgments

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notes

1. Antichaos is defined by Stuart Kauffman as a counterintuitive phenomenon where "some very disordered systems spontaneously 'crystallize' into a high degree of order" (Kauffman 1991a: 78). Alternatively, Cohen and Stewart (1994: 411) refer to it as 'simplexity,' "the emergence of large-scale simplicities as a direct consequence of rules," or laws of nature. Predictable laws interact with unpredictable contingencies to trigger the collapse of chaos. Then simple rules emerge from the underlying disorder and complexity.

2. For an overview of the concept of stitches in the sewing together of a narrative, see Marcus Doel's innovative paper on the work of Jacques Deleuze and Felix Guattari (Doel 1993).

3. It was noted by Resnick (1994) that the children who participated on his research programme tended to confuse levels of reality during cell-space explorations; for instance, the turtles and their respective actions were humanized.

4. The theory of island biogeography has been inverted, for in Kauffman's formulation, a "frozen component" acts as a barier to the spread of information, whereas the extension of sea ice in glacial periods is thought to have acted as a bridge for cultural and biotic diffusion.

5. An alternative name for this co-evolution of systems is provided by Cohen and Stewart's term 'complicity,' which occurs when "the tendency of interacting systems to coevolve in a manner that changes both, [leads] to a growth of complexity from simple beginnings – which is unpredictable in detail, but whose general course is comprehensible and forseeable" (1994: 3).

6. Bhaba (1990) provides an explanation of these hybrid, interstitial spaces associated with postcolonial identities.

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Outward Bound

I could choose to rest, to glory in
the smooth glacial slopes of isolation
my form reflected on the arctic's deep
I could abide on ice floes glowing
generous white as my skin, and
buried in Aurora's blue-snow-sleep
dream the echo of my native speech
crystal banks refracting voice and light
spilling the tundra flush with tones of me
white on white, a swelling insulation

but, selling my mother's diamonds for the fare
and knowing the place will scorch my skin
beyond all repair, I still choose
the high noon of your so southern love
walking the line where north meets south
feet bare, sun-blistered for the tight-rope stunt
bedsores from the lumpy seam where sex is stitched
two poles, worlds, flags, lives, bodies stewed
the equatorial mists rise sizzling from the mix
salt for the earth and meet for each other
flesh/bone baked and broiled as one
we'll make our love on the burning meridian

Sheila Hassell Hughes
1991-97